Course of Action Ontology for Counterinsurgency Operations

Timothy Darr, Perakath Benjamin, Richard Mayer
Knowledge Based Systems, Inc.

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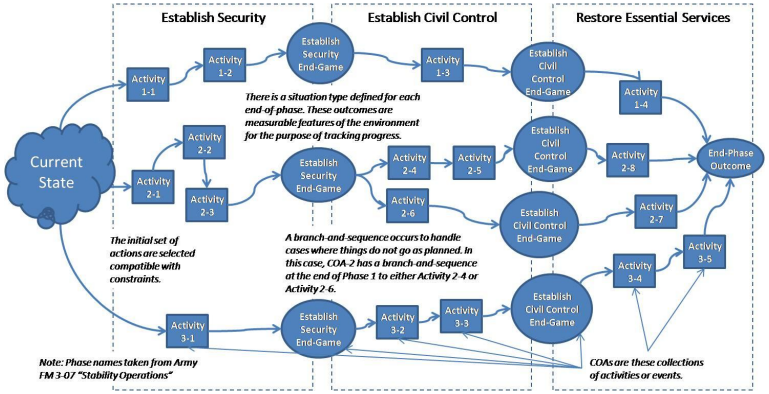
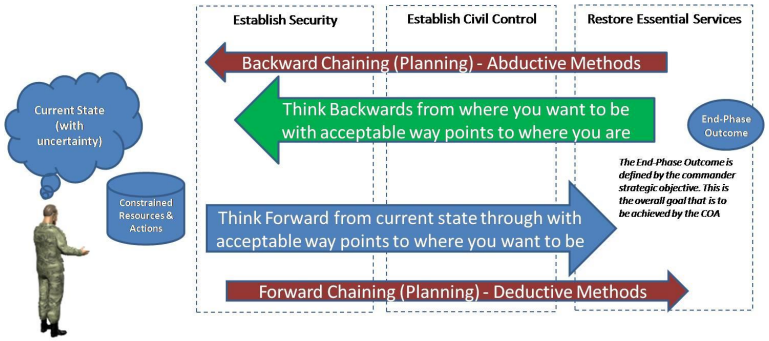
Outline

- **Introduction**
- Planning Process Context
- COA Ontology
- Technical Approach
- Practical Value to the COA Planner
- Summary and Future Work

Introduction

- The Deep Maroon *course of action (COA) ontology* supports COA design, analysis and selection
  - Includes representations of
    - Courses of action
    - Phases and logical lines of operations
    - COA activities, states, outcomes
    - Measures of performance and measures of effectiveness
- Deep Maroon is a *middleware capability* to assist planners in gap analysis
  - interleaved forward (from COAs to meet commander's objective) and backward (from commander's objective to possible COAs) reasoning methods





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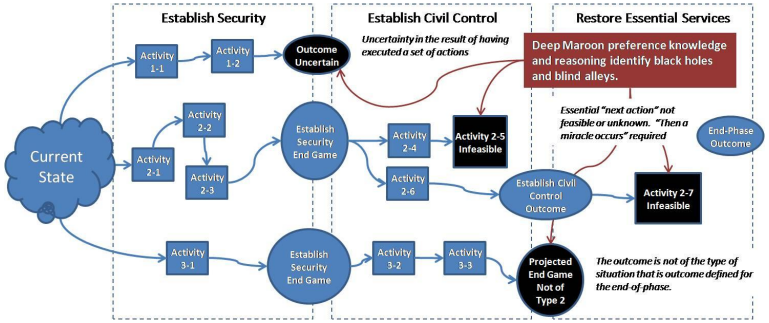
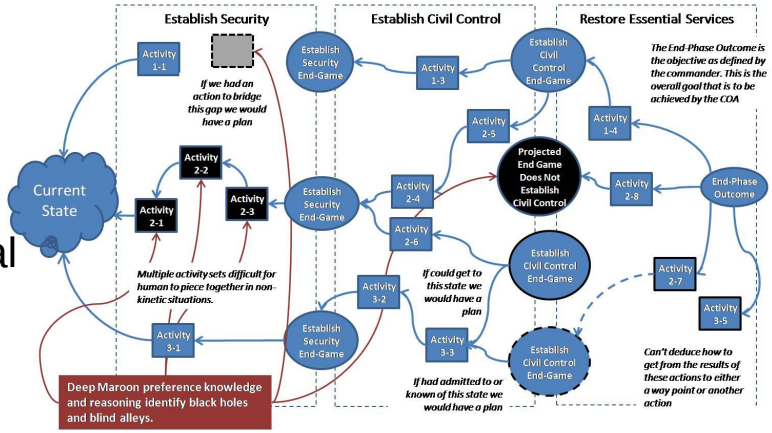
Introduction

- Deep Maroon *preference model* represents decision-maker trade-offs to resolve conflicting objectives
- Applications include:
  - ranking and assessing COA plan elements,
  - identifying blind alleys and black holes,
    - Black holes lead to an inflammatory situation such as civil war or increased intra-militia violence.
    - Blind alleys are unproductive states with no feasible next state or no path to a goal state.
  - validating or challenging assumptions that are implicit in the COA or preference model,
  - validating or modifying Human Social Cultural Behavior (HSCB) models of the adversary, local population, the "unaligned middle", or other group of interest, and
  - assessing information operations (IO) MOP and MOE





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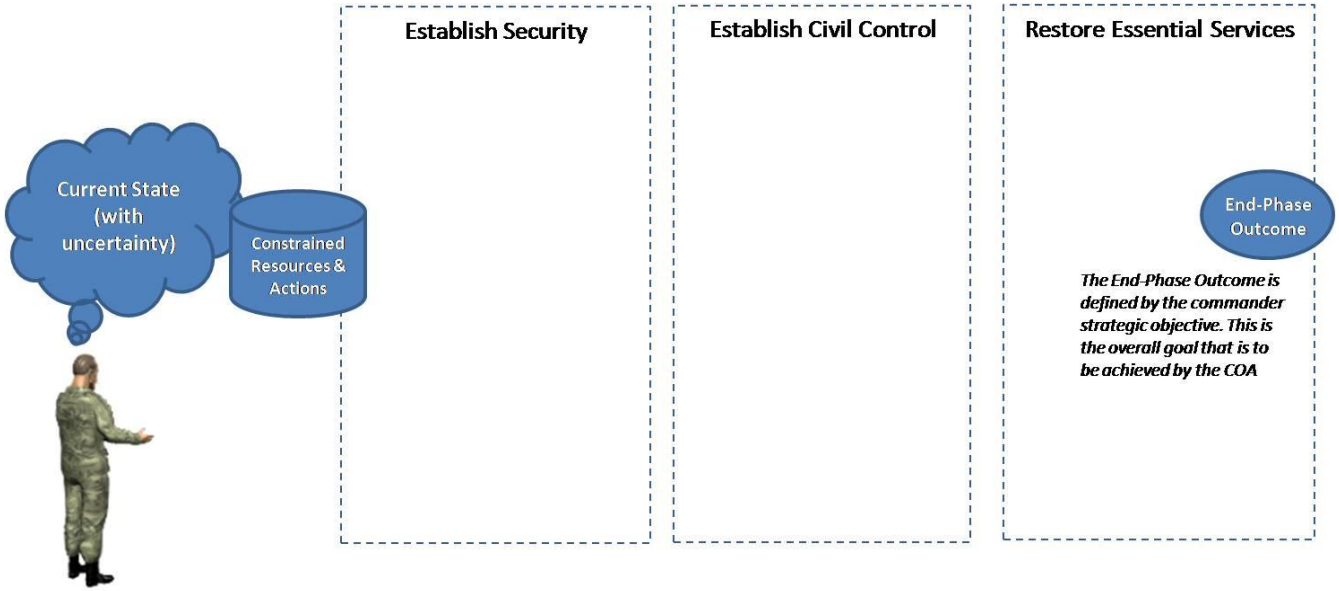
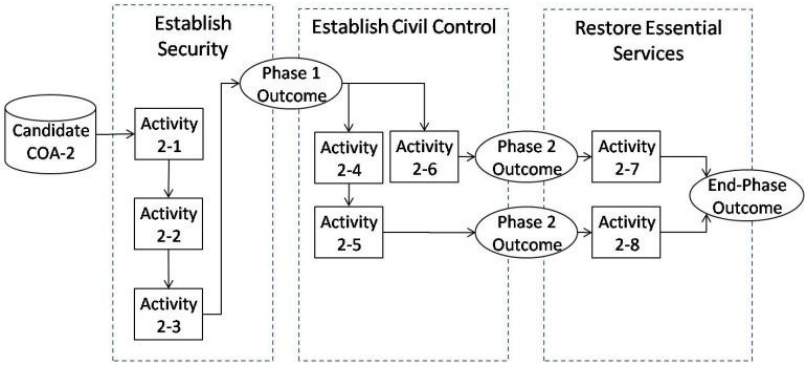
Planning Process Context



Given a commander's objective in which essential services are to be restored in an urban or semi-urban environment, the decision-maker is faced with the challenge of achieving interim objectives to achieve the ultimate goal.



Note: Phase names taken from Army FM 3-07 "Stability Operations"

Each phase is terminated by an outcome that serves as a milestone for measuring progress of the plan. Each phase contains a sequence of activities that are performed to achieve the end-phase outcomes. The activities can be sequential, as shown in the establish security and restore essential services phases; or branch-and-sequence as shown in the establish civil control phase.

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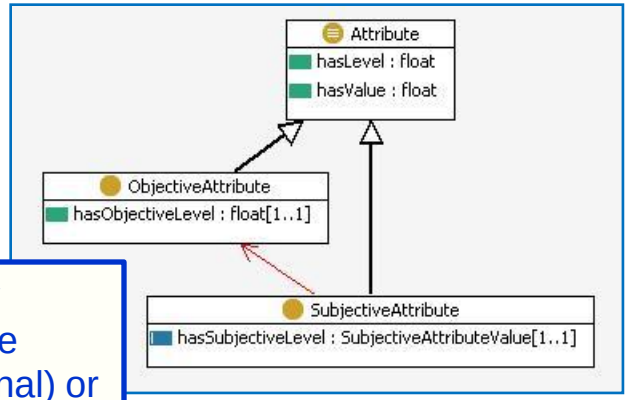
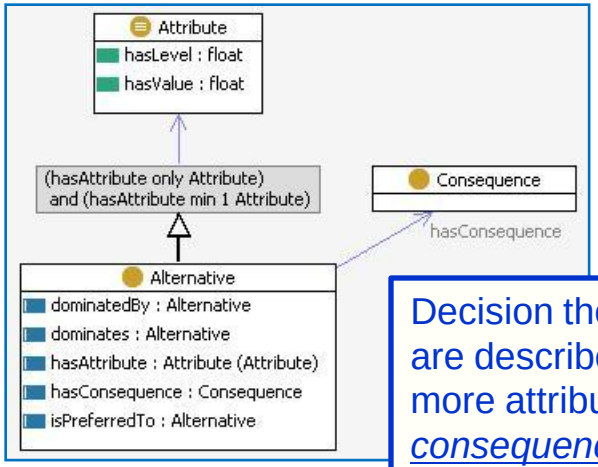
COA Ontology

- The Deep Maroon COA ontology is intended to support COA planning
- Based on a multi-attribute utility-theory (MAUT) decision problem as formulated by Keeney and Raiffa (Keeney, R.L. and Raiffa, H. “Decisions with Multiple Objectives: Preferences and Value Tradeoffs”, Wiley and Sons, New York, 1976)
  - Defines alternatives, attributes, preferences, dominance relationships …
- Applies to the COA planning process as defined for the U.S. Army and Marine Corps for multiple domains, including:
  - stability operations planning (FM 3-07),
  - counterinsurgency operations planning (FM 3-24) and
  - information operations planning (FM 3-13)
- Consists of multiple sub-ontologies containing a small number of concepts that are easily integrated into other ontologies
  - Measures of effectiveness, measures of performance, urban COIN
- Includes mapping from the COA planning domain to the MAUT decision problem

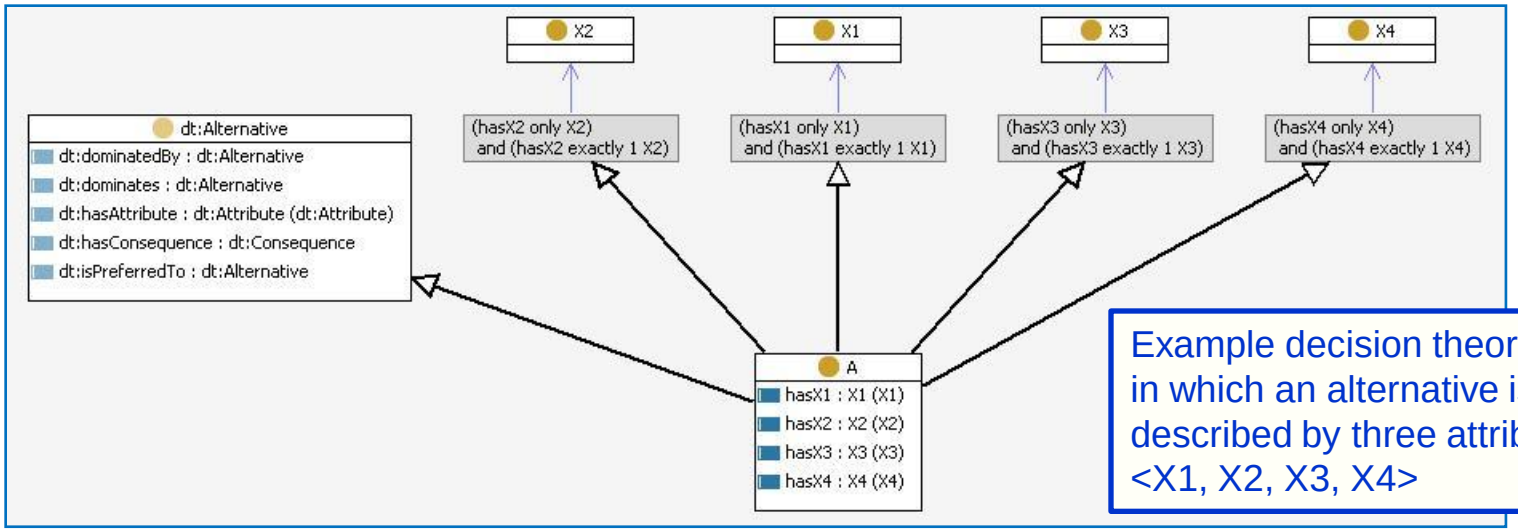
COA Ontology – Decision Theory Concepts



Decision theory *attributes* can be *subjective* (ordinal) or *objective* (numeric).



Decision theory *alternatives* are described by one or more attributes and have a *consequence*



Example decision theory problem in which an alternative is described by three attributes: <X1, X2, X3, X4>

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COA Ontology – Decision Theory Evaluators

dt:levelEvaluator

```
# Level evaluator for high values
CONSTRUCT {
  ?this dt:hasLevel 500.0 .
}
WHERE {
  ?this dt:hasSubjectiveLevel ?level .
  FILTER (?level = dt:high) .
}

# Level evaluator for low values
CONSTRUCT {
  ?this dt:hasLevel 50.0 .
}
WHERE {
  ?this dt:hasSubjectiveLevel ?level .
  FILTER (?level = dt:low) .
}

# Level evaluator for medium values
CONSTRUCT {
  ?this dt:hasLevel 100.0 .
}
WHERE {
  ?this dt:hasSubjectiveLevel ?level .
  FILTER (?level = dt:medium) .
}
```

SPARQL rules compute the *utility-theoretic value* for each attribute (objective or subjective). These values represent the desirability or utility of the attribute level, from a given perspective.

For objective attributes, the *level* is the numeric measure of that attribute. For subjective attributes, SPARQL rules compute the level for the attribute.

dt:valueFunction

```
# Piecewise value function for levels between 5.0 and 7.0
CONSTRUCT {
  ?this dt:hasValue 0.5 .
}
WHERE {
  ?this dt:hasLevel ?level .
  FILTER ((?level < 7.0) && (?level > 5.0)) .
}

# Piecewise value function for levels less than 5.0
CONSTRUCT {
  ?this dt:hasValue 0.0 .
}
WHERE {
  ?this dt:hasLevel ?level .
  FILTER (?level <= 5.0) .
}

CONSTRUCT {
  ?this dt:hasValue 1.0 .
}
WHERE {
  ?this dt:hasLevel ?level .
  FILTER (?level >= 7.0) .
}
```

$$V_{X_1}(a_i) = \begin{cases} 0.0 \; if \; V_{X_1}(a_i) \leq 5.0 \\ 0.5 \; if \; 5.0 < V_{X_1}(a_i) < 7.0 \\ 1.0 \; if \; V_{X_1}(a_i) \geq 7.0 \end{cases}$$

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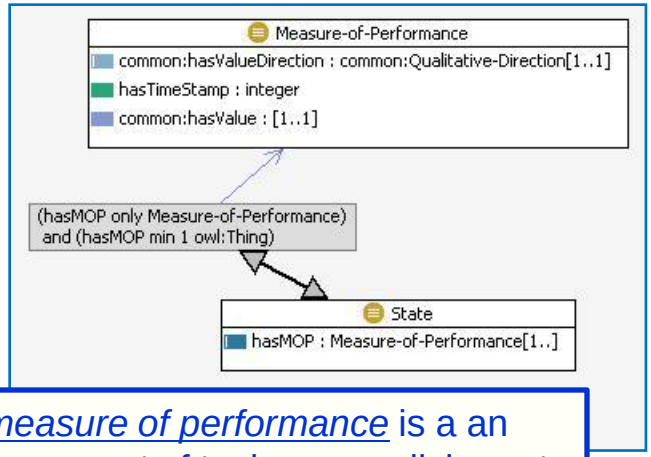
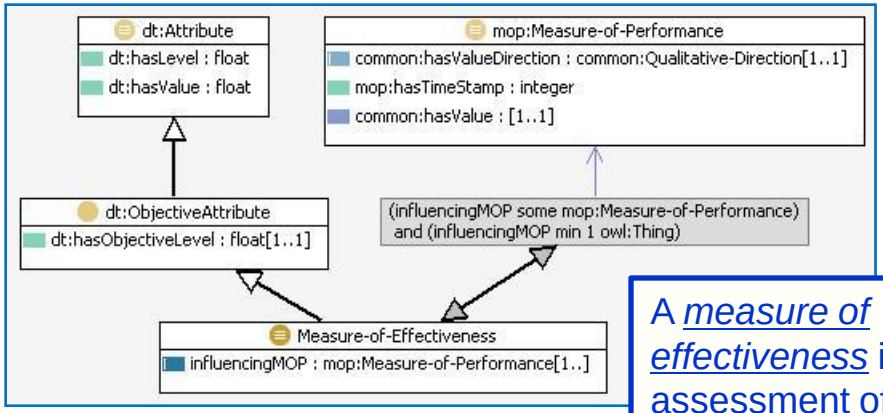
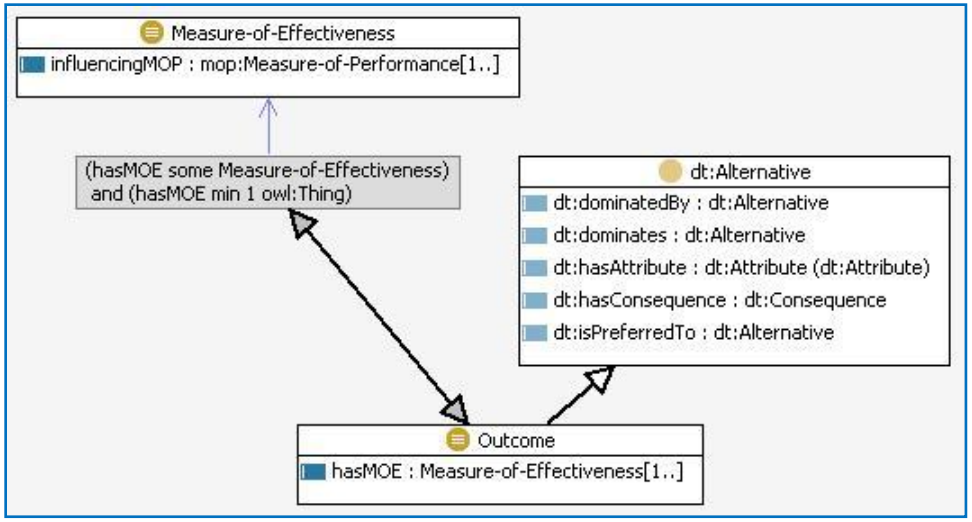
COA Ontology – COA Domain Elements



A *measure of performance* is a an assessment of task accomplishment. *States* are a descriptions of the world in terms of MOPs.



A *measure of effectiveness* is a an assessment of objective achievement. MOPs *influence* MOEs.



An *outcome* is a decision-theoretic alternative that is described by one or more MOEs.

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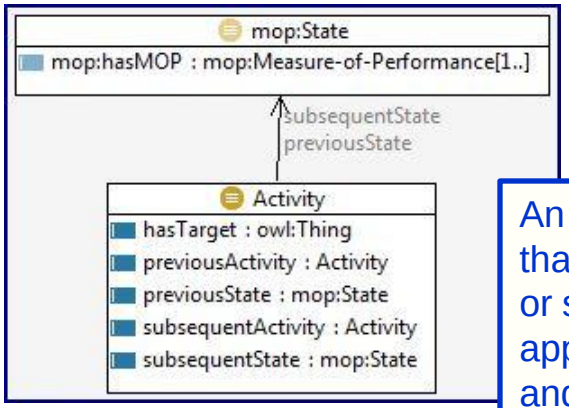
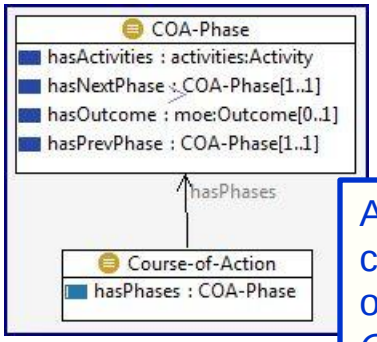
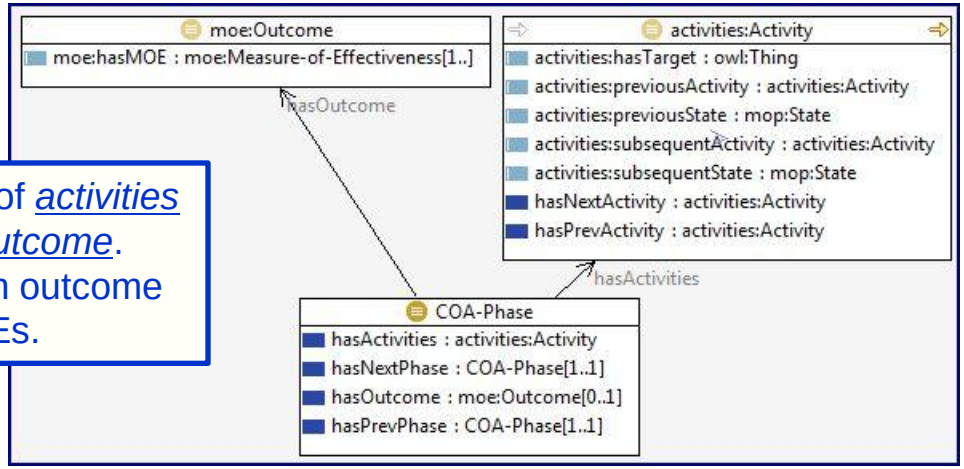


An *activity* is an action that can have a previous or subsequent activity, applies in a given state and results in a next state.



A *COA* consists of one or more *COA Phases*.

COA Phases consist of *activities* and have a desired *outcome*. Accomplishment of an outcome is determined by MOEs.



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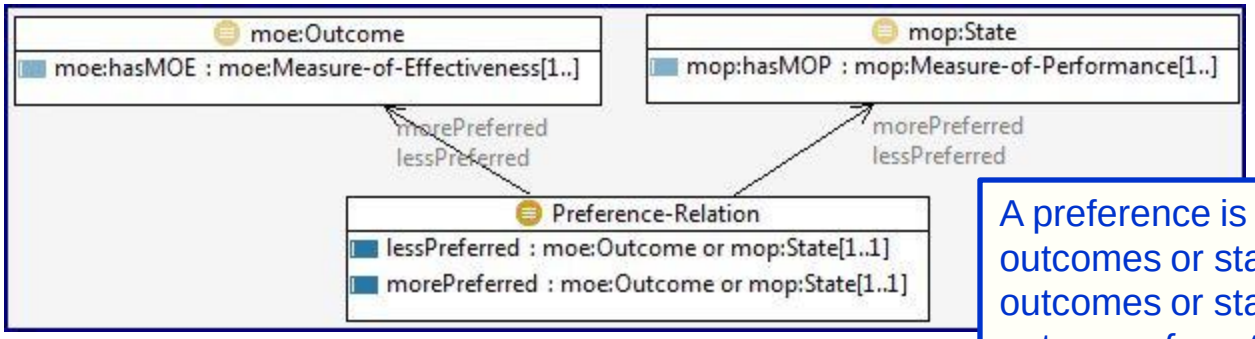
COA Ontology – Preferences



A preference is a relation between two outcomes or states in which one of the outcomes or states *is preferred to* the other outcome, *from the perspective of* a commander, decision maker, social / cultural group or other entity

Example preferences within the COIN domain include:

- In an agricultural community in which there is little or no electricity, a COA whose outcome involves restoration of economic self-sufficiency via the building or restoring a canal system for crop irrigation, will be *preferred to* a COA in which the same outcome is achieved via the activity of providing electrical power to the local market

Preference reasoning provides a way to *rank-order* outcomes or states from the perspective of a given interest group (counterinsurgents, insurgent group, religious or ethnic group, etc.).

An inference algorithm can use these preferences to reason about assessment of how a given outcome or state will be perceived and can assist a planner in the identification of *black holes or blind alleys*.

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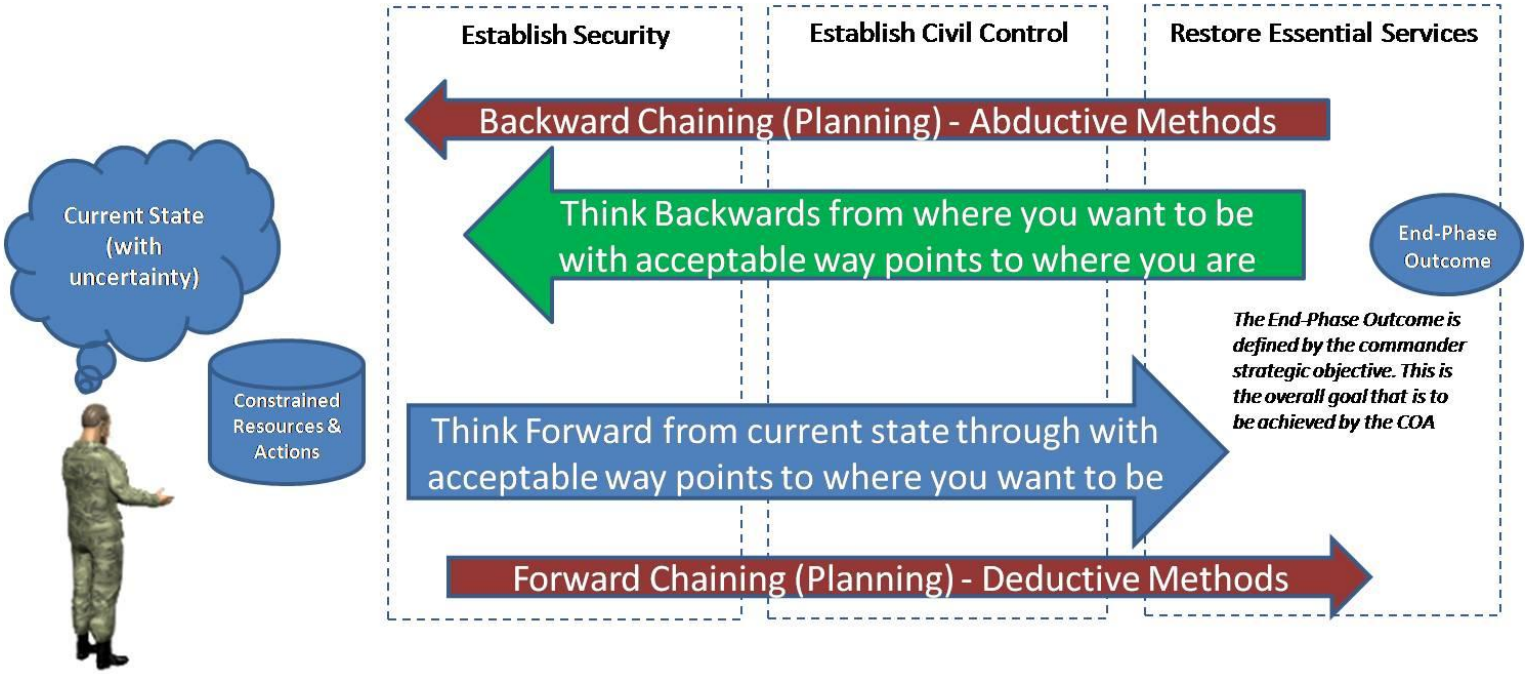
Technical Approach – COA Assessment



Typically, a small number of COAs are developed by the commander's staff based on a mission statement, the commander's intent and the commander's planning guidance. A subset of the developed COAs are designated by the commander for war gaming. During war gaming, the commander's staff determines the advantages and disadvantages of each designated COA, based on the enemy response (most likely, most dangerous to the blue forces, most advantageous to the blue forces) and battle space.

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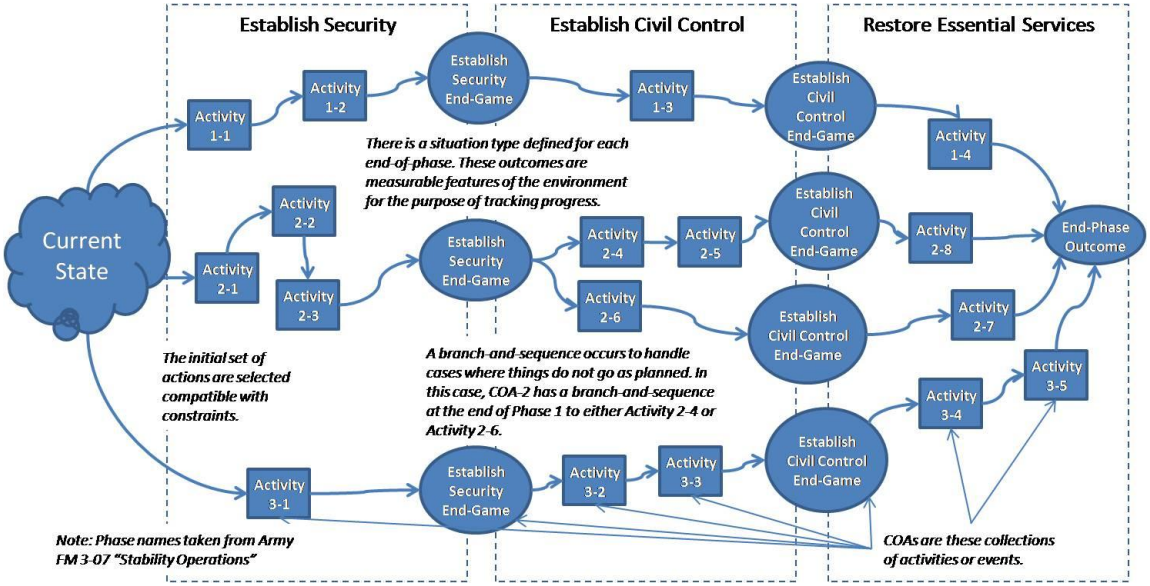
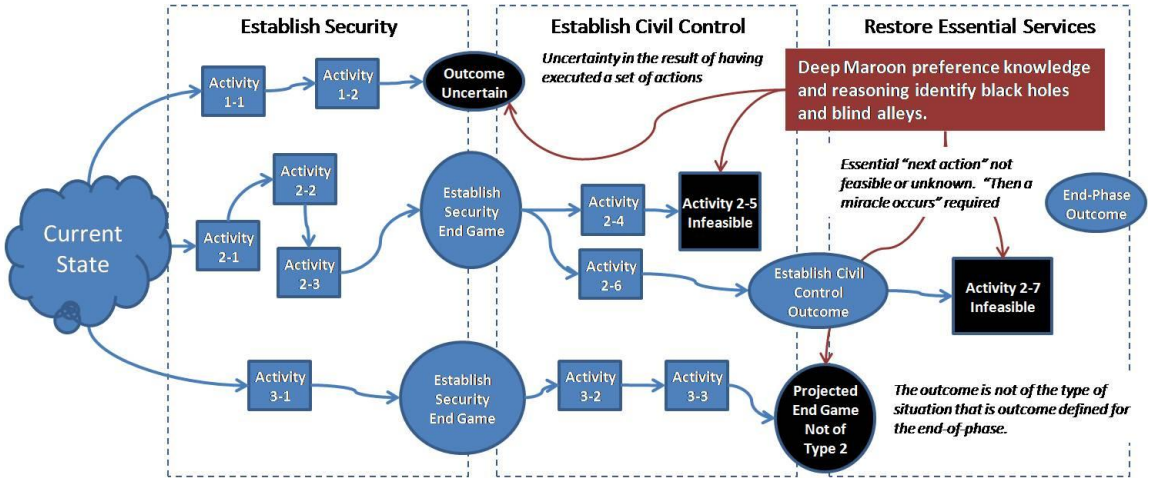
Technical Approach – Forward Reasoning



Goal-directed forward chaining reasoning provides a way to reason about the desired trajectory of the plan over time (forward chaining).

In thinking forward from the current state, the possible activities that are possible in a given state are determined.



The sequence of activities that are available at each plan state can be determined by matching activity preconditions with the current state and asserting the new state that results from the application of the activity.

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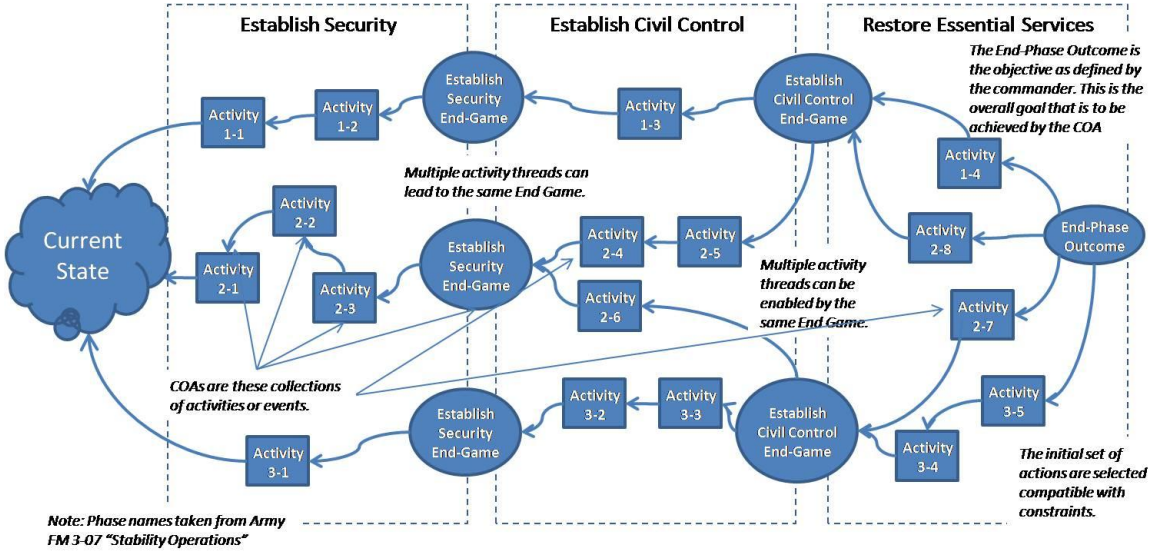
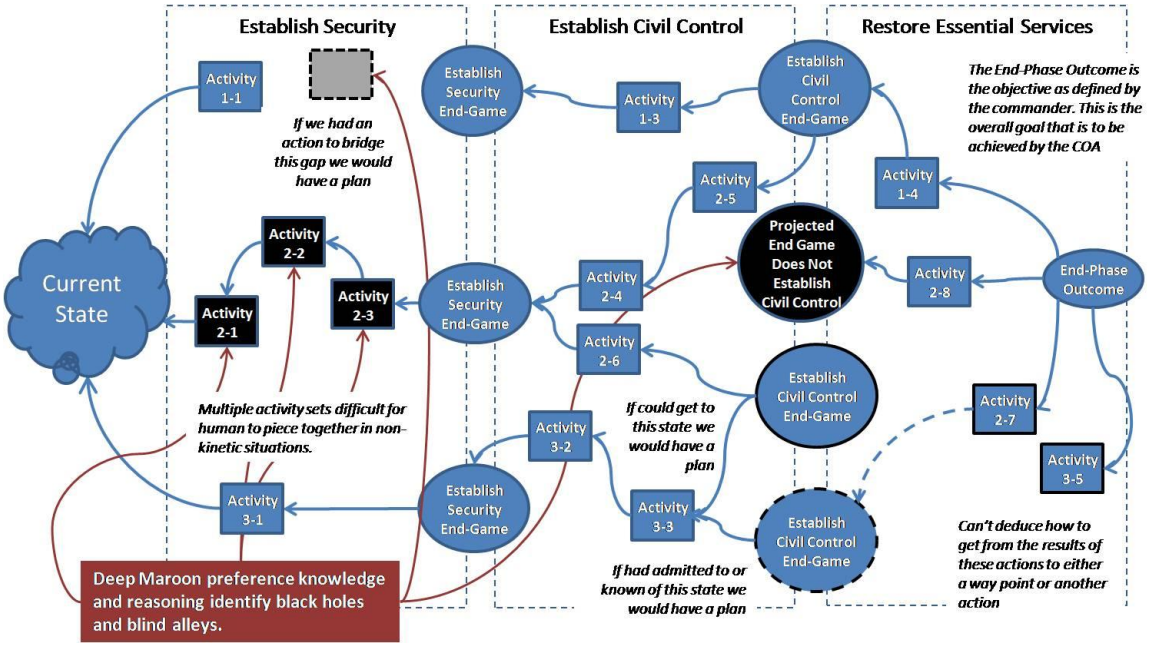
Technical Approach – Backward Reasoning





Given a (end) state, goal-directed backward chaining reasoning provides a way to determine a set of prior (starting) states that would result in that (end) state (backward chaining).

In thinking backward from the desired end-state, the possible states that lead to a given outcome, and the possible activities that can achieve those states, are determined.

Abductive methods allow the inference of what must be true for an MOE to be achieved, or a task or activity to be applied. That is, if state S is known and action A is known to result in a state S then we assume A occurred to produce S.

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Technical Approach – Gap Analysis

- Ideally, forward and backward reasoning will yield the same states, activities, and end-phase outcomes
- More likely, there will be gaps in the plan, or disagreements in the results of the forward and backward reasoning.
- If there are disagreements, then this indicates that
  - there are assumptions in the creation of the preference models that must be challenged (the models need to be modified in some way),
  - the MOPs and MOEs that describe states and outcomes must be revisited,
  - the activities need to be analyzed against the assumed previous and subsequent states.

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Practical Value to the COA Planner

- Well-defined MOP and MOE for describing COA plan states and outcomes
- MOP and MOE-based metrics for evaluating the progress of the plan as it unfolds
- Normalization of the effects of an activity, described as changes in state or outcomes, allowing disparate activities and plans to be compared
- A catalog of COIN activities defined by the states in which an activity applies and the expected states that result after application of the activity
- A utility-theoretic preference model that represents the trade-offs that a group of interest (blue forces, insurgents, unaligned middle, etc.) makes over conflicting objectives
- The ability to assess COA plan states, activities and outcomes from the perspective a specific interest group

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Summary and Future Work

- This presentation described a COA ontology and a preliminary technical approach for a COA design, analysis and selection tool
- The initial version of the ontology supports:
  - A MAUT model of decision problems
  - Definitions for COA activities, phases, MOEs, MOPs
  - Inference rules for value calculation, dominance relationships, preferences
  - Mapping from the MAUT model to COA planning
- Future work includes:
  - Continue to develop the COA ontology
  - Develop preference models for specific socio-cultural groups
  - Develop inference rules for constructing activity paths
  - Develop capabilities to reason about black holes and blind alleys
  - Explore options for verification and validation
    - SME feedback
    - Mining historical data for comparison of actuals vs. forecasted

Questions / Feedback

Timothy Darr
Research Scientist II
tdarr@kbsi.com
Knowledge Based Systems, Inc.

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